International Journal of GEOMATE, June, 2024 Vol.26, Issue 118, pp.96-104
ISSN: 2186-2982 (P), 2186-2990 (O), Japan, DOI: https://doi.org/10.21660/2024.118.4409
Geotechnique, Construction Materials and Environment

WORKABILITY, MECHANICAL AND DURABILITY INVESTIGATIONS ON SELF-COMPACTING CONCRETE WITH HIGH FLY ASH CONTENT AND RECYCLED FINE AGGREGATE

Nguyen Hung Cuong

Faculty of Building and Industrial Construction, Hanoi University of Civil Engineering, Vietnam

*Corresponding Author, Received: 30 Jan. 2024, Revised: 03 May 2024, Accepted: 13 May 2024

ABSTRACT: Currently, in Vietnam, the natural sand resource is depleted; thus, it is unable to meet the growing demand for construction. In this context, recycled fine aggregate (RFA) from waste concrete emerges as an effective alternative for sand in the production of self-compacting concrete (SCC). In this paper, the author presents the experimental results on the properties of SCC with high fly ash content using RFA. The research utilizes RFA to replace natural sand at the rates of 0% and 100%, respectively while applying fly ash concurrently at a 50% volume ratio of cement. The evaluated properties of the SCC include its workability, compressive strength, flexural tensile strength, chloride ion permeability, and water absorption. The research results show that the use of RFA combined with high fly ash content can produce SCC that meets EFNARC requirements, with only a 1.48% reduction in compressive strength, 1.85% decrease in flexural tensile strength, 19.79% reduction in chloride ion permeability, and 5.12% increase in water absorption compared to the use of natural sand. These findings demonstrate the effectiveness of incorporating RFA and high fly ash to replace natural sand and cement in SCC production, opening up prospects in the construction industry with positive environmental impacts.

Keywords: Self-compacting concrete, Workability, Concrete strength, Chloride ion permeability, Recycled fine aggregate

1. INTRODUCTION

In Vietnam's construction industry, the use of natural sand plays a crucial role when the demand for construction and infrastructure development continues to rise. Statistical data from various regions of the country indicates an annual consumption of approximately 120-130 million m^3 of natural sand for construction. From 2016 to 2020, sand used for groundfilling reached 2.1-2.6 billion m^3. However, the remaining natural sand reserved for construction and ground filling is only about 2.1 billion m^3 [1]. This depletion highlights the gradual scarcity of natural sand, posing challenges to the construction industry. Moreover, excessive exploitation of natural sand not only severely impacts the natural ecological environment but also leads to serious issues such as landslides and changes in river flow. In response to this challenge, the government actively promotes policies to replace natural sand with recycled sand [2]. However, research and application of recycled sand in the concrete industry have certain limitations.

Recycled Fine Aggregate (RFA) for concrete is a reclaimed product from waste and old concrete structures, which is then processed and recycled to produce new concrete. Compared to natural sand in conventional concrete, RFA tends to have higher water absorption [3, 4], contains more fines, and has smaller particle sizes [5]. Integrating RFA into concrete could result in reduced compressive strength [6, 7]. Additionally, the interfacial transition zone (ITZ) becomes more complex when old cement paste adheres to RFA [5]. Moreover, drying shrinkage tends to increase when using RFA as a fine aggregate entirely [8]. The chloride ion permeability of concrete also tends to decrease [9, 10]. On the other hand, the high water absorption capacity of RFA reduces the workability of the concrete mix, especially under hot and dry climate conditions [11].

Self-compacting concrete (SCC) is a specialized type of concrete known for its high consistency and excellent workability. It can flow through formwork under its own weight without the need for vibration, ensuring strong compaction [12]. While the use of SCC has such benefits as fast construction, reduced reliance on labor and equipment, improved working conditions for workers, noise reduction, and environmental protection, the costs of material and quality control remain higher than traditional concrete [13]. Therefore, it is essential to have more research on alternatives such as recycled aggregates and high fly ash content to minimize production costs.

Several studies worldwide have shown that SCC with recycled fine aggregates can achieve acceptable compressive strength and workability [14-16]. According to [17], the use of industrial byproducts such as crushed sands can address both economic and environmental concerns. Meanwhile, fly ash, a byproduct from thermal power generation, has been utilized for construction, such as road base material and landfill cover, and as a substitute for sand and cement, which is environmentally sustainable [18].

Studies suggest that using high fly ash content significantly reduces the production cost of SCC [19]. Fly ash also acts to reduce permeability, decrease water demand, and lower the heat of hydration, thereby enhancing the SCC's workability [20] and reducing carbon emissions [18]. In the study by Kou [16], the effectiveness of combining RFA with fly ash in SCC production was demonstrated. Therefore, the combined usage of RFA and high fly ash content in SCC production can partially overcome the drawbacks of RFA. This approach can create low-cost SCC, reduce resource consumption and have significant environmental benefits. Figure 1 illustrates the recycling process of RFA in Hanoi.

Fig.1 Recycling process of RFA from waste concrete in Hanoi

At present, there is limited research on the properties of SCC utilizing both Recycled Fine Aggregate (RFA) and high fly ash content, especially within the specific context of materials and climate conditions of Vietnam. This study marks a new direction as the author explores the use of recycled fine aggregates derived from waste concrete and F-type fly ash to produce SCC. The investigation involves RFA content, comprising 0% and 100% by volume of fine aggregate, along with fly ash content set at 50% by volume of cement. The properties of the SCC under scrutiny include workability, compressive strength, flexural tensile strength, chloride ion permeability and water absorption. Consequently, this research aims to provide a comprehensive understanding of the characteristics of SCC with high fly ash content using recycled fine aggregates.

2. SIGNIFICANCE OF THE RESEARCH

The natural sand source in Vietnam is increasingly depleted and cannot meet the demands for infrastructure construction. Meanwhile, concrete waste from construction activities is growing and has adverse effects on the ecological environment. In this study, the author investigated the properties of SCC with high fly ash content using RFA. Evaluated properties included workability, compressive strength, flexural strength, chloride ion permeability and water absorption of SCC. The research results will provide a basis for the application of RFA in SCC production, aiming to manufacture sustainable concrete. It contributes significantly to addressing solid waste from construction activities and plays a vital role in conserving natural resources.

3. EXPERIMENTAL MATERIALS AND MIX PROPORTIONS

3.1 Materials Used

The materials employed in the experiment include Vicem But Son PC40 Cement, having density of 3.1 g/cm³; Golden Sand from the Red River having density of 2.65 g/cm³ and water absorption rate of 1.22%; RFA crushed from concrete waste, characterized by a density of 2.31 g/cm³ and water absorption rate of 4.28%; Coarse Aggregate (Dmax = 20 mm) consisting of crushed stone having density of 2.75 g/cm³; Fly Ash from the Pha Lai thermal power plant, categorized as Type F fly ash following ASTM C618 standards; Superplasticizer (SD): incorporating the new-generation BiFi-HV298 superplasticizer, enhanced with a polymer base with a density of 1.05 and adheres to ASTM C-494 Type G standards; Viscosity-Modifying Admixture (VMA): employing Culminal MHPC400 as a viscosity-modifying agent. The particle composition of RFA and sand is depicted in Figure 2.

The experimental materials were provided by Transmeco Concrete Company Limited, located at km 12, QL1A, Vinh Quynh, Thanh Tri, Hanoi.

RFA used in the research was manufactured by processing the concrete wastes obtained from demolition projects in Hanoi, Vietnam. The recycling process involved crushing the waste at a station located in Dong Anh district, Hanoi. The sand, after being crushed, is dried and sieved. Thereafter, those particles larger than 5mm are removed from the final materials before experimentation. Figure 3 shows the RFA obtained from recycled concrete waste.

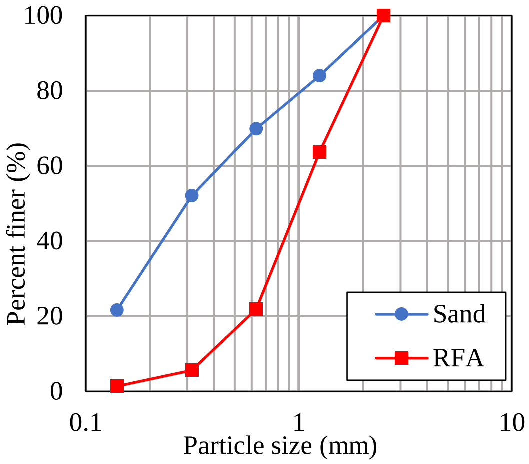

Fig. 2 Shows the particle size distribution curve of RFA and sand

Fig. 3 Shows RFA obtained from concrete waste

3.2 Experimental Concrete Mix Proportions

Nowadays, there are various guidelines for designing SCC. However, it can be observed that the processes are divided into two groups: (i) designing based on compressive strength criteria, and (ii) designing based on the criteria of required workability [21]. In this research, the author chose the second group to conduct his research. Specifically, the mix design for SCC was carried out using the method proposed by Akamura and Ozawa [22]. According to this method, the fine aggregate (sand) is fixed at 40% of the paste volume, while the coarse aggregate (stone) occupies 50% of the concrete volume, with an assumed ratio (W/P) in the range of 0.9 to 1. The superplasticizer dosage is adjusted according to the workability requirements, at approximately 1% of the powder content.

Following the guidelines [22], two different mix proportions were used in the experiment for evaluation. These mix proportions were created by varying the amount of recycled aggregate, with 0% and 100% recycled aggregate content respectively, while maintaining a fixed ratio of fly ash/powder (FA/P) equal to 0.5 and water/powder (W/P) equal to 0.4. The detailed mix proportions for one m^3 of SCC are presented in Table 1, where RFA 0 and RFA 100 correspond to 0% and 100% recycled fine aggregate content, respectively.

4. EXPERIMENTAL RESULTS

4.1 SCC Workability Test

The workability test of the SCC mixtures was carried out in accordance with the guidelines outlined in TCVN 12209:2018 [23]. The experimental parameters included slump flow (SF), T_{500} time, V_{funnel} time, L_{box} flowability, J_{ring} value and segregation resistance (Sr). Specifically, the slump flow (SF) represents the average diameter of the SCC mixture when flowing out of the standard slump cone; T_{500} time indicates the time taken for the SCC mixture to achieve a diameter of 500 mm during the slump flow test using the standard slump cone; the J_{ring} value reflects the height difference of the SCC mixture between the center and outer edge of the J_{ring}; L_{box} flowability is the ratio of the height of the SCC mixture measured at the endpoint (H2) and the starting point (H1) of the horizontal edge of the L_{box} apparatus (H2/H1) after the SCC mixture flows through the L_{box}; V_{funnel} flowability is the time taken for the SCC mixture to flow completely through the bottom of the V_{funnel}; and segregation resistance (Sr) of the SCC mixture is its ratio passing through a 5mm square sieve.

In the experiment, the initial workability was measured immediately after the completion of mixing. To assess the reduction in workability of the SCC mixture over time, the workability parameters were re-measured every 30 minutes, for the total period of 120 minutes. The climatic conditions recorded in the Hanoi area indicated an environmental temperature of 32^{o}C and humidity of 75%. According to [24], the SF value should fall within the range of 650-800mm, T_{500} time between 2-5 seconds, J_{ring} value from 0-10 mm, V_{funnel} time between 6-12 seconds, and Sr between 5-15%.

The experimental results showed that the workability of both mixtures, RFA 0 and RFA 100, met the requirements of EFNARC. The results of the workability test, including SF, T_{500} time, J_{ring}, L_{box}, V_{funnel}, and Sr, are presented in Table 2. Figure 4 illustrates the workability of the SCC mixture.

Table 2. Results of workability testing according to TCVN 12209:2018

Mixture	SF (mm)	T_{500} (s)	V_{funnel} (s)	L_{box}	J_{ring} (mm)	Sr (%)
RFA 0	700	2.56	7.90	0.93	8.5	7.8
RFA 100	685	3.54	9.60	0.85	9.1	6.9

Table 1 Mix proportions for 1 m^3 of SCC

Mixture	Cement (kg)	Fly ash (kg)	Sand (kg)	RFA (kg)	Stone (kg)	Water (kg)	Superplasticizer (kg)	VMA (kg)
RFA 0	264.1	264.1	748.8	0.0	770	211.3	2.11	0.37
RFA 100	264.1	264.1	0.0	748.8	770	211.3	3.84	0.37

(a) The SF test (b) The V_{funnel} test (c) The Sr test

Fig.4 SCC workability test

According to the results of the workability test in Table 2, when using 100% recycled fine aggregate (RFA 100), the slump flow decreased by 2.14% compared to the mixture using natural coarse aggregate (RFA 0). It can be observed that using 100% RFA in the composition can produce SCC mixtures with slightly reduced slump flow, but this can be compensated by adjusting the superplasticizer dose and also by using a high-volume fly ash. In this research, the supplementary dosage of superplasticizer increased by 81% compared to the RFA 0 mixture (Figure 5).

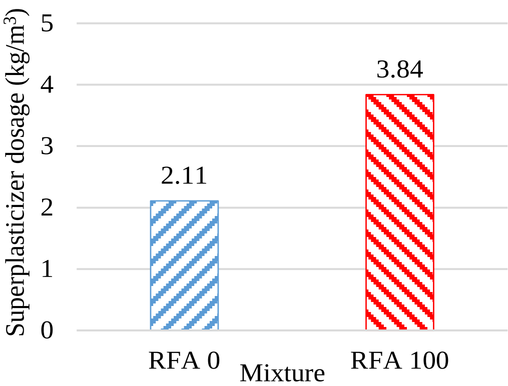

Fig.5 Superplasticizer dosage used in SCC production

However, for 100% RFA, due to the high water absorption of the RFA, the viscosity of SCC mixtures tends to increase. The increased viscosity is reflected in the T_{500} time, decreased V_{funnel} time, and increased L_{box} and J_{ring} values. In addition, a significant advantage of RFA usage is the reduced segregation resistance compared to using natural aggregate, with a reduction of approximately 11.5%. Visual observation of the J_{ring} for both RFA 0 and RFA 100 mixtures showed no segregation or water bleeding, indicating uniform distribution of materials on the J_{ring}. It demonstrates that both SCC mixtures are homogeneous and possess good workability.

Under hot and humid weather conditions in Hanoi, with an ambient temperature of 32°C and 75% humidity, the RFA 100 mix maintains good slump flow and ensures workability after more than 30 minutes of retention according to the usage criteria (SF ≥ 650) and around 70 minutes according to classification criteria (SF ≥ 550, SF2 ≥ 660, SF3 ≥ 760). However, the RFA 0 mix still maintains good slump flow after 120 minutes of retention. Figure 6 illustrates the decrease in slump flow (SF) of the SCC mixture with RFA 0 and RFA100 aggregate gradations.

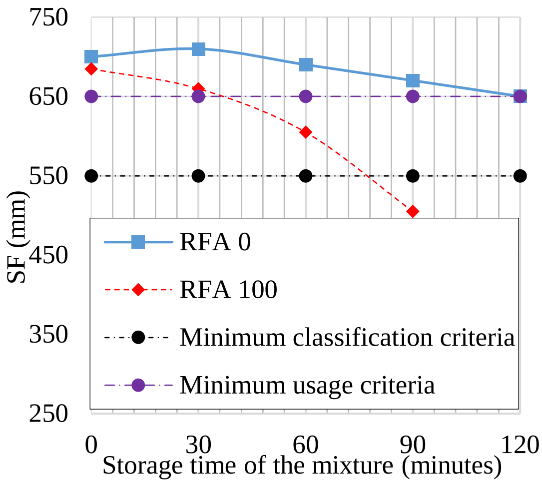

Fig.6 SF reduction of SCC mixtures over time

The high water absorption characteristic of RFA significantly influences the reduction in viscosity of the mixture through the Vfunnel and T_{500} parameters. When using natural aggregate, the RFA

0 mix has V-funnel parameters reduced beyond the usage standard ($V_{funnel} \leq 12$ seconds) after approximately 60 minutes of retention, while T500 remains below the usage standard ($T_{500} \leq 5$ seconds) until around 120 minutes. Particularly, when using 100% RFA in the RFA 100 mix, Vfunnel exceeds the standard after 45 minutes, and T_{500} exceeds the standard after 60 minutes (Figure 7).

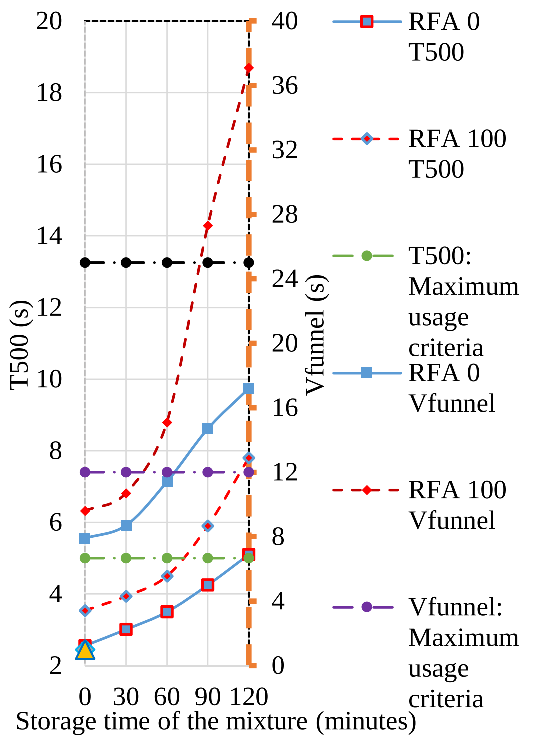

Fig.7 Reduction in T_{500} and V_{funnel} parameters of SCC mixtures over time

The impact of the ability to pass through the apparatus on viscosity also correlates with the water absorption of the SCC mixture, as seen in the Lbox and Jring parameters. Specifically, when using natural aggregate, the RFA 0 mix satisfies both usage standards: $J_{ring} \leq 10$mm up to 70 minutes and $L_{box} \geq 0.8$ up to 90 minutes. However, when using 100% RFA, the RFA 100 mix has Jring parameters maintained only up to 30 minutes, and L_{box} is sustained for 30 minutes of retention (Figure 8).

It can be observed that under the same climatic conditions, the high water absorption of the aggregate is the main factor causing the rapid reduction in the workability of the SCC mixture. Additionally, the rougher surface structure of RFA compared to natural sand, along with some fine particles of RFA being old cementitious paste that can present hydraulic properties, also affects the flowability of the SCC mixture [14]. The SCC mixture is assessed as having adequate workability when it meets all required parameters at the time of pouring into the mold. In the hot and humid weather conditions of the experiment, the workability of the SCC mixtures using RFA can only be maintained for a relatively short period, around 30 minutes. In contrast, the SCC mixtures using natural aggregate maintains good workability for up to 60 minutes. The experimental results align with the study conducted by Carro-López [14], which showed that the workability of SCC mixtures using RFA deteriorated significantly after 45 minutes compared to SCC using natural sand. However, the different environmental temperature and humidity conditions between the two studies may lead to variations in the duration of workability loss for SCC mixtures. The rapid loss of workability of the SCC mixtures is a disadvantage when using RFA. Therefore, to ensure the required workability, reducing the retention time of the mixture, organizing transportation and pouring concrete quickly are crucial factors when applying RFA for SCC in construction projects.

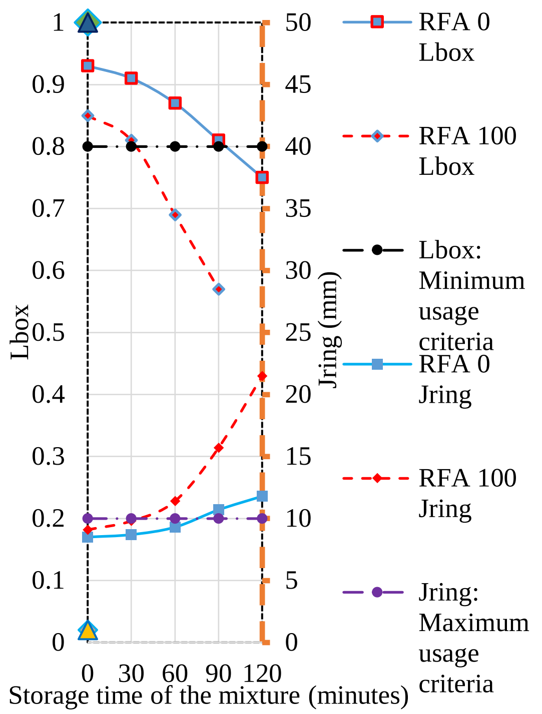

Fig.8 Reduction in L_{box} and J_{ring} parameters of SCC mixtures over time

4.2 Results of Compressive Strength and Flexural Tensile Strength Tests for SCC

Concrete samples were taken, cast, and cured according to TCVN 3105:2022 [25]. The specimens were cast and cured for one day in steel molds under laboratory air conditions, then demolded and cured by immersion in water until 28 days of age. The compression strength specimens had dimensions of 10x10x10cm. Compressive strength testing was conducted following TCVN 3118:2022 [26]. The flexural tensile strength specimens had dimensions of 150x150x600mm. The determination of the flexural tensile strength of concrete specimens was carried out according to the guidelines of TCVN 3119:2022 [27]. The specimens were tested at 28 days of age. Figure 10 shows the compressive strength results of SCC mixtures. Figure 9a illustrates the flexural testing of the RFA 100 specimens.

The experimental results revealed that the compressive strength of RFA 0 and RFA 100 mixtures (Figure 10) was 40.3 MPa and 39.7 MPa, respectively, at 28 days of age. The use of 100% RFA resulted in a 1.48% reduction in SCC compressive strength compared to the mixture using natural sand. The experimental compressive strength results of SCC are quite consistent with the study by Tabsh [28] for concrete with low cement content (compressive strength of 30 MPa). The study found that using 100% RFA significantly reduced the compressive strength of concrete, with an average reduction of about 5%. Additionally, according to the research by Kou [16], the properties of SCC made from RFA and natural sand show only minor differences. The lower quality of RFA compared to natural sand negatively impacts the compressive strength. However, RFA may contain unhydrated cement, which, upon contact with water, activates bonding properties and benefits the compressive strength of concrete [28]. Therefore, the use of RFA has a relatively insignificant impact on the compressive strength of SCC compared to the use of natural sand.

The flexural tensile strength (R_k) and flexural tensile strength (R_{ku}) of RFA 100 were 4.85 MPa and 2.81 MPa, respectively, which were 1.85% lower than those of RFA 0, with values of 4.76 MPa and 2.76 MPa, respectively. Figure 11 illustrates the flexural tensile strength and axial tensile strength of SCC.

Visual inspection of the cross-sectional damage of RFA 0 and RFA 100 specimens (Figure 9.b) showed uniform concrete damage occurring through the aggregate particles. This indicates that the use of RFA can still achieve good bonding between the mortar layer and the large aggregate particles in SCC. Consequently, compressive strength and flexural tensile strength value of SCC using RFA insignificantly decreased compared to SCC using natural sand.

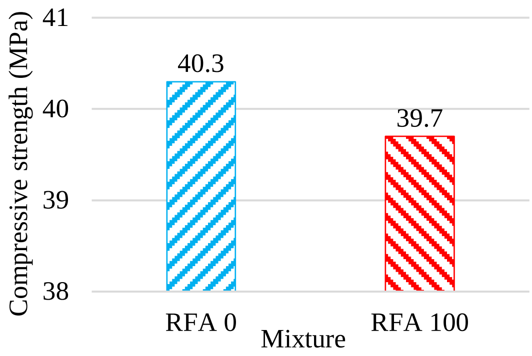

Fig.10 Compressive Strength of SCC

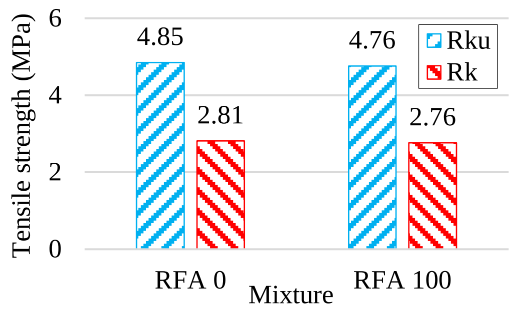

Fig.11 Flexural tensile strength and axial tensile strength of SCC

4.3 Chloride Ion Permeability and Water Absorption Tests

Concrete samples were cast and cured according to TCVN 3105:2022 [25]. The specimens were cast and cured for one day in steel molds under laboratory air conditions, then demolded and cured by immersion in water until 28 days of age. The water absorption specimens had dimensions of 100x100x100mm. The water absorption determination was conducted following the guidelines of TCVN 3113:2022 [29]. The chloride

(a) RFA 100 Flexural Test

(b) Cross-sectional damage of RFA 100 specimen

Fig.9 RFA 100 Flexural Test

ion permeability test was of TCVN 3113:2022 [29]. The chloride ion permeability test was performed using the RCPT method as per the guidelines of TCVN 9337:2012 [30]. The test was conducted by passing a direct current through cylindrical specimens with a diameter of 100 mm and a height of 50 mm. One face of the test specimen was exposed to a 3% NaCl solution connected to the negative electrode, while the other face was exposed to a NaOH solution connected to the positive electrode. The chloride ion permeability was evaluated by measuring the charge passed through the specimen over a period of 6 hours. The specimens were tested at 28 days of age.

The RCPT results at 28 days indicated a charge passed through RFA 0 and RFA 100 samples were 1096 C and 1313 C, respectively. Therefore, the charge passed through the RFA 100 sample increased by 19.79% compared to the RFA 0 sample. The increased chloride ion permeability when using RFA is attributed to three main reasons according to [8]: (i) the presence of a large amount of old mortar adhering to the surface of RFA leading to increased porosity, facilitating chloride ion penetration, (ii) the old mortar layer absorbing water and reaching saturation, hindering the transition zone between the old and new dense mortar, allowing for easy chloride ion transmission, (iii) recycled aggregate materials having high porosity and diffusion coefficient, enhancing electrical conductivity, thus increasing the charge passing through the concrete when using RFA. However, the charge passing through both RFA 0 and RFA 100 samples fell within the range of 1000-2000 C, classifying the concrete as having low permeability according to TCVN 9337:2012 [30]. Figure 12 illustrates the RCPT test results.

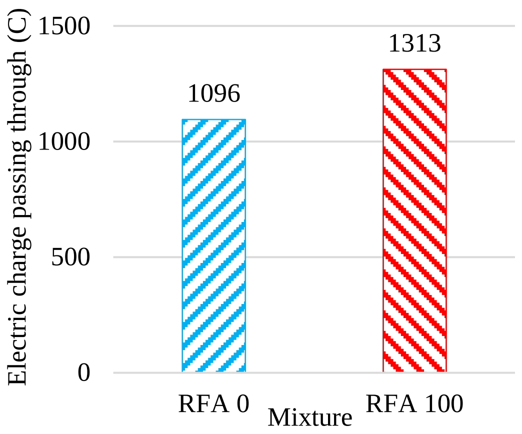

Fig.12 Chloride ion permeability results

Water absorption for RFA 0 and RFA 100 were 1.95% and 2.05%, respectively. Compared to the control sample (RFA 0), water absorption for the mixture using 100% RFA increased by approximately 5.12%. This increase is attributed to the higher water absorption of RFA compared to natural sand, causing a small portion of RFA on the outer surface of the concrete to absorb water and reach a saturated state. However, due to the inherently impermeable nature of the SCC mortar layer and its difficulty in water penetration, water is less likely to infiltrate the inner concrete layers. Figure 13 displays the water absorption results for SCC.

In summary, the results of the chloride ion permeability and water absorption tests for SCC indicate that the use of high-volume fly ash has significantly mitigated the drawbacks associated with RFA. The incorporation of high-volume fly ash in this research has resulted in SCC with low chloride ion permeability and water absorption. This improvement is attributed to the pozzolanic reaction of fly ash, which produces hydro-halting products, filling voids and enhancing the compactness of SCC. Additionally, fly ash has higher chloride ion absorption and binding properties than cement, thereby, reducing chloride ion permeability.

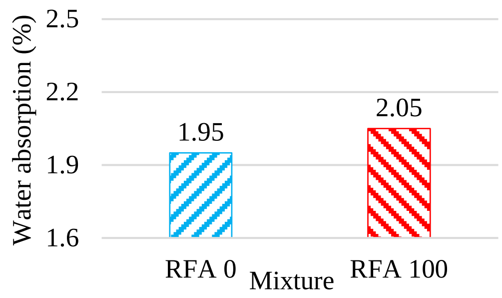

Fig.13 Water absorption test results

5. CONCLUSIONS

In the context of depleting natural sand resources and serious environmental impact, the research and application of RFA with high fly ash content in the production of SCC in Vietnam represents a significant and innovative step forward. This research focused on investigating the properties of SCC under the material and climate conditions of Vietnam, paving the way for sustainable construction. In the research, several key conclusions regarding the properties of SCC when using RFA were as below:

The workability of the SCC mix when using RFA meets the requirements of EFNARC by increasing the content of superplasticizer, viscosity-modifying admixture and combining with the use of high-volume fly ash. In this research, the superplasticizer content in SCC using RFA increased by 81% compared to SCC using natural sand.

The workability of the SCC mix using RFA decreases more rapidly than SCC using natural sand. Under hot and humid climate conditions with an environmental temperature of 32°C and 75% humidity, the workability of SCC using RFA remains good for approximately 30 minutes. In contrast, the SCC mix using natural sand can maintain good workability for up to 60 minutes of storage.

The compressive strength of SCC using RFA decreases by 1.48%, and the flexural tensile strength decreases by 1.85% compared to SCC using natural sand.

The chloride ion permeability of SCC using 100% RFA increases by 19.79% and water absorption increases by 5.12% compared to SCC using natural sand.

The use of recycled fine aggregates (RFA) combined with fly ash and high-content superplasticizers can produce self-compacting concrete (SCC) with properties (workability, compressive and flexural strength, chloride ion permeability, and water absorption) that are insignificantly different from those of natural sand. The research results pave the way for the application of low-cost and environmentally friendly SCC in construction projects in Vietnam. Future researches could be expanded to explore variations in the use of RFA, water-to-cement ratio, and fly ash-to-cement ratio to promote wider adoption of RFA in concrete production.

6. REFERENCES

[1] Dung L.V., Kien T.T., Thanh D.D., Lam N.B., Experimental research to estimate the application of crushed limestone sand For concrete of axial loading R-C column, Journal of Science and Technology in Civil Engineering, Vol.15, Issue 3V, 2021, pp. 93-103.

[2] Decision No. 1266/QD-TTg, Approval of the Development Strategy for Construction Materials in Vietnam for the period 2021-2030, with orientation towards 2050, Prime Minister, 2020, pp.1-31.

[3] González-Taboada I., González-Fonteboa B., Martínez-Abella F. and Carro-López D., Study of recycled concrete aggregate quality and its relationship with recycled concrete compressive strength using database analysis, Materiales de Construcción, Vol.66, Issue 323, 2016, pp.e089-e089.

[4] Pereira P., Evangelista L.M.F.D.R. and De Brito J.M.C.L., The effect of superplasticizers on the mechanical performance of concrete made with fine recycled concrete aggregates, Cement and concrete composites, Vol.34, Issue 9, 2012, pp.1044-1052.

[5] Zhang H., Ji T., Zeng X., Yang Z., Lin X. and Liang Y., Mechanical behavior of ultra-high performance concrete (UHPC) using recycled fine aggregate cured under different conditions and the mechanism based on integrated microstructural parameters, Construction and Building Materials, Vol.192, 2018, pp.489-507.

[6] Carro-López D., González-Fonteboa B., De Brito J., Martínez-Abella F., González-Taboada I. and Silva P., Study of the rheology of self-compacting concrete with fine recycled concrete aggregates, Construction and Building Materials, Vol.96, 2015, pp.491-501.

[7] Grdic Z.J., Toplicic-Curcic G.A., Despotovic I.M. and Ristic N.S., Properties of self-compacting concrete prepared with coarse recycled concrete aggregate, Construction and Building Materials, Vol.24, Issue 7, 2010, pp.1129-1133.

[8] Bu C., Liu L., Lu X., Zhu D., Sun Y., Yu L., OuYang Y., Cao X. and Wei Q., The Durability of recycled fine aggregate Concrete: A Review, Materials, Vol.15, Issue 3, 2022, 1110, pp.1-18.

[9] Mardani-Aghabaglou A., Tuyan M. and Ramyar K., Mechanical and durability performance of concrete incorporating fine recycled concrete and glass aggregates, Materials and Structures, Vol.48, 2015, pp.2629-2640.

[10] Zhenhua D., Shaodan H., Zhisheng P., Shanshan J. and Jianzhuang X., Rheology of recycled fine aggregate concrete and its influence on strength and durability, Journal of Building Structures, Vol.41, Issue S2, 2020, pp.411-419.

[11] Acker A.V., Recycling of concrete at a precast concrete plant, Proceedings of the Sustainable Construction: Use of Recycled Concrete Aggregate, 1998, pp.321-332.

[12] Elevado K.J.T., Galupino J.G. and Gallardo R.S., Artificial neural network (ANN) modelling of concrete mixed with waste ceramic tiles and fly ash, GEOMATE Journal, Vol.15, Issue 51, 2018, pp.154-159.

[13] Tuyan M., Mardani-Aghabaglou A. and Ramyar K., Freeze-thaw resistance, mechanical and transport properties of self-consolidating concrete incorporating coarse recycled concrete aggregate, Materials & Design, Vol.53, 2014, pp.983-991.

[14] Carro-López D., González-Fonteboa B., Martínez-Abella F., González-Taboada I., de Brito J. and Varela-Puga F., Proportioning, fresh-state properties and rheology of self-compacting concrete with fine recycled aggregates, Hormigón y Acero, Vol.69, Issue 286, 2018, pp.213-221.

[15] Corinaldesi V. and Moriconi G., The role of industrial by-products in self-compacting concrete, Construction and Building Materials, Vol.25, Issue 8, 2011, pp.3181-3186.

[16] Kou S.C. and Poon C.S., Properties of self-

compacting concrete prepared with coarse and fine recycled concrete aggregates, Cement and Concrete composites, Vol.31, Issue 9, 2009, pp.622-627.
[17] Amulya G., Moghal A.A.B. and Almajed A., Sustainable binary blending for low-volume roads-Reliability-based design approach and carbon footprint analysis, Materials, Vol.16, Issue 5, 2023, pp.2065-2094.
[18] Moghal A.A.B., Rehman A.U., Vydehi K.V. and Umer U., Sustainable perspective of low-lime stabilized fly ashes for geotechnical applications: promethee-based optimization approach. Sustainability, Vol.12, Issue 16, 2020, pp.6649-6667.
[19] Bouzoubaa N. and Lachemi M., Self Compacting concrete incorporating High Volumes of Class F fly ash: Preliminary results, Cement and concrete Research, Vol.31, 2001, pp.413-420.
[20] Douglas R.P., Properties of self-consolidating concrete containing type F fly ash (No. Item Code: SN2619), International RILEM Symposium on Concrete Science and Engineering: A Tribute to Arnon Bentur, 2004, pp.1-84
[21] Daczko J., Self-consolidating concrete: applying what we know, Spon Press Publisher, 2012, pp.1-288.
[22] Okamura H. and Ozawa K., Mix design for self-compacting concrete, Concrete library of JSCE, Vol.25, Issue 6, 1995, pp.107-120.
[23] TCVN Standard 12209:2018, Self-compacting concrete - Specification and test method, Construction Publisher, 2018, pp.1-22.
[24] Bibm, Efca, Efnarc, Ermco and Cembureau, The European guidelines for self-compacting concrete: Specification, Production and Use, 2005, pp.1-63.
[25] TCVN Standard 3105:2022, Heavyweight concrete compound and heavyweight concrete - Samling, making and curing of test specimens, Construction Publisher, 2022, pp.1-6.
[26] TCVN Standard 3118:2022, Hardened concrete - Test method for compressive strength, Construction Publisher, 2022, pp.1-13.
[27] TCVN Standard 3119:2022, Hardened concrete – Test method for flexural tensile strength, Construction Publisher, 2022, pp.1-8.
[28] Tabsh S.W. and Alhoubi Y., Experimental Investigation of Recycled Fine Aggregate from Demolition Waste in Concrete, Sustainability, Vol.14, Issue 17, 2022, pp.10787-10802.
[29] TCVN Standard 3113:2022, Hardened concrete - Test method for water absorption, Construction Publisher, 2022, pp.1-8.
[30] TCVN Standard 9337:2012, Heavy concrete - Method for electrical indication of concrete's ability to resist chloride ion penetration, Construction Publisher, 2012, pp.1-10.